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ORIGINAL RESEARCH

A FOUR-WEEK TRAINING PROGRAM WITH THE NORDIC HAMSTRING EXERCISE DURING PRESEASON INCREASES ECCENTRIC STRENGTH OF MALE SOCCER PLAYERS

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ABSTRACT

Background: The Nordic hamstring exercise (NHE) is an effective strategy to prevent hamstring strain injuries in soccer players. The current literature recommends a 10-week training program with three sessions per week, but the short preseason period and the congested schedule make difficult for high-performance soccer teams to apply the NHE as recommended.

Purpose: The purpose of this study was to examine the effect of a pragmatic NHE training program during a four-week preseason period on eccentric knee flexor strength of high-performance soccer players.

Study design: Quasi-experimental clinical trial.

Methods: This study included 25 under-20 male soccer players from a premier league club. They performed eight sessions of NHE (3 sets of 6-10 repetitions, twice a week) during the four-week preseason period. The eccentric knee flexor strength was evaluated during the NHE execution on a custom-made device, before and after the training program.

Results: The NHE training program significantly increased the players' eccentric knee flexor strength in both right ($\Delta = 13\%$; $p < 0.001$; effect size = 0.97) and left limbs ($\Delta = 13\%$; $p < 0.001$; effect size = 0.92). Individual analysis identified 76% of the players as responders to the NHE training program ($\Delta = 16\%$; effect size = 1.60), and 24% as non-responders ($\Delta = 3\%$; effect size = 0.24).

Conclusion: A four-week training program with NHE performed twice a week is feasible in the real-world of high-performance soccer clubs and increases the eccentric knee flexor strength of male soccer players.

Keywords: Eccentric training, Football, Injury prevention, Sports physical therapy.

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INTRODUCTION

The hamstring strain injury (HSI) is the most common non-contact injury in soccer.[1] An elite club can expect around 5-6 of their players to suffer at least one HSI per season, and more than half of the injuries usually prevent participation for periods of 8-28 days.[2] The HSI relapse rate is high,[2] and the rehabilitation process is often more complicated in re-injuries.[3] As a consequence, the HSI affects team performance negatively and causes financial loss to the clubs,[4] which increasingly invest in resources to screen the most susceptible players and in intervention programs focused on injury prevention.[5,6]

Between 60% and 80% of soccer HSIs occur during high speed running;[7,8] more specifically at the end portion of the balance phase, when the fibers contract eccentrically, decelerating the knee extension and the hip flexion movements.[3] That is the reason why poor eccentric strength is traditionally identified as an important risk factor for HSI.[9] Prospective studies have supported that soccer players with low capacity to produce eccentric knee flexor strength are more likely to HSI during the season,[8,10–12] as well as observed in other sports.[13,14] Thus, hamstring eccentric strengthening is a traditional goal of injury prevention programs in soccer, such as the "FIFA 11+", developed by *Fédération Internationale de Football Association* (FIFA).[15]

The so-called Nordic hamstring exercise (NHE) is one of the most popular strategies for HSI prevention in soccer players.[5,6,15] Arnason et al.[16] and Petersen et al.[17] demonstrated the preventive effect of a 10-week NHE training program (followed by a maintenance schedule along the season) in randomized controlled trials with large sample sizes of soccer players. According to the meta-analysis by Al Attar et al.,[18] training programs with the NHE reduce by half the HSI rate of soccer players from different competitive levels, supporting the inclusion of this kind of exercise in injury prevention programs.

The muscular strengthening provided by NHE is commonly considered to be one of the main mechanisms responsible for reducing the HSI incidence during the soccer season. Mjolnes et al.[19] were the first to demonstrate that a 10-week NHE training program enhances the eccentric knee flexor strength of soccer players. Ishoi et al.[20] and Lovell et al.[21] further demonstrated the positive strength response of soccer players engaged in 10-12 weeks of NHE training. However, it is important to note that high-performance clubs hardly ever have such long preseason periods.[5,6] This difficulty of transposing the intervention used by scientific studies to the real world of high-performance sport might justify the low compliance by premier league soccer clubs.[22]

Ribeiro-Alvares et al.[23] found that a four-week NHE training program significantly enhanced the eccentric knee flexor strength of physically active adults. However, the muscle strength response is likely training-status dependent; thus, extrapolating the research findings obtained in different populations to highly trained athletes requires caution, and randomized clinical trials performed with high-level athletes have greater validity for the elite sport environment.[24] Therefore, the objective of this study was to examine the effect of a pragmatic NHE training program during a four-week preseason period on eccentric knee flexor strength of high-performance soccer players.

METHODS

Study design

This clinical trial was carried out through a partnership between the authors' research group (hosted in Federal University of Health Sciences of Porto Alegre, Brazil) and a national first division soccer club. The NHE training program was included in the preseason training routine of the under-20 team. Eccentric knee flexor strength was assessed one week before the start and one week after the end of the four-week NHE training program.

Participants

This study included male soccer players aged from 18 to 20 years old (i.e., under-20 category). All players had professional contracts with a Brazilian first division soccer club, and experience in national and international competitions. The following exclusion criteria were adopted: (1) history of muscle injury at the posterior thigh within six months before the start of the study; (2) musculoskeletal injuries of the lower limbs or in other body areas that would interfere in the training development and/or in

the evaluation protocols during the data collection period; (3) difficulty understanding and/or performing the test and training protocols; and (4) poor compliance to the NHE training program (i.e., subjects should attend the eight training sessions).[25]

The study was carried out during the preseason period. Players had up to six weekly training sessions on the soccer field and two training sessions in the gym. Goalkeepers were not included in this trial because they performed specific training and have a lower risk of HSI. Therefore, all participants of the study were engaged in the same training routine under supervision of the coaching staff. They were also monitored by the club's nutritionist, physician, and physiotherapists. Traditional strength training at the gym was performed concurrently with the NHE training program, which was performed at the field. Trunk, lower body and upper body exercises were performed with free weights and gym machines, always monitored by the strength and conditioning trainer. The leg curl was the only specific gym exercise for knee flexors; this exercise promotes the knee flexor concentric strengthening, but has not been able to influence the eccentric strength of this muscle group.[18] NHE is very popular among soccer teams, thus all players had previous experience with this exercise, but none of them followed a systematized training program before the study began.

This study was approved by the institutional ethics in research committee. All the volunteers were informed about the study purpose and procedures, and all agreed to participate by signing a consent term.

Procedures

Hamstring strength evaluation

A device to measure the eccentric knee flexor strength during the NHE execution was built especially for the current study (Figure 1), based on a prototype validated[26] and used in previous studies.[13,14,27] The volunteer was positioned to perform the NHE on a platform, and commercially available load cells (E-lastic; *E-sporte Soluções Esportivas*, Brasilia, Brazil) with simultaneous transference of data via bluetooth were fastened around his ankles (right above the lateral malleolus). The volunteer was instructed

Figure 1. *Evaluation of the eccentric knee flexor strength during the NHE execution. The white arrows highlight the two load cells used for data acquisition.*

to execute the NHE as the following: from the initial position (kneeling, with the hip neutral and the torso upright), lay the torso towards using only the knee joint (e.g., without altering the position of hips or spine), in slow speed and using eccentrically the hamstring muscle with the maximum intensity and amplitude possible to avoid the acceleration and consequent torso fall. The volunteer would have to use his upper limbs to absorb the fall, and return to the initial NHE position.

For strength measurement, subjects performed a minimum of three NHE valid attempts (i.e., proper movement execution), with at least 10-second rest periods between them. The force produced by each lower limb was registered, and the highest value (peak force) among the valid attempts was used for statistical analysis. All players were familiarized with the NHE, and the proper testing execution was demonstrated before data collection. They

were instructed not to consume any stimulating substance, medicine or alcoholic beverages during the 24 hours before the test performance.

The reliability of the NHE testing device was previously assessed. A group of 19 physically active men with at least two sportive practice sessions per week (24.00±3.91 years old; 74.13±8.19 kg; 1.79±0.06 m) performed the same evaluation procedure on the NHE device in two occasions separated by four weeks. Results supported a high test-retest reliability: ICC = 0.94, typical error = 15.17 N (5.01%). This reliability level was slightly better than values reported by the previously validated prototype [ICC = 0.83-0.90; typical error = 22-27 N (6-8%)].[26]

NHE training program

The NHE sessions were performed twice a week (with at least 48-hour breaks between sessions) during a four-week period, coinciding with the club preseason training schedule. A progressive volume periodization was based on previous studies with this kind of intervention (Table 1).[23,25] The NHE sessions were always performed on the soccer field, after the team's regular warm-up (applied by the strength and conditioning trainer, and including both general and specific warm-up exercises) and before the regular soccer training. The exercise was performed in pairs (i.e., the players helped each other by holding the ankles of the one who was doing the NHE; later, they switched the roles). A researcher followed every session to ensure the right implementation of the training volume (number of sets and number of repetitions per set) and the proper execution of the NHE.

Statistical Analysis

Data normality was assessed through the Shapiro-Wilk test. Paired sample t-test was used to compare the eccentric knee flexor strength before and after the NHE training program. Practical significance of training-induced changes was assessed through the effect size (Cohen's d): $d = (A_{post} - A_{pre})/DP_{group}$, in which A_{post} is the post-training average, A_{pre} is the pre-training average, DP_{group} is the standard deviation of pre- and post-training measures grouped]. The effect sizes were classified as trivial ($d < 0.2$), small ($d > 0.2$), moderated ($d > 0.5$) or large ($d > 0.8$).[28]

Individual responsiveness to NHE training used the two-limb average value of percent change (pre- to post-training). Responders and non-responders were determined using the typical error criteria.[29,30] The typical error (TE) of measurement was calculated through the following equation: $TE = SD_{diff}/\sqrt{2}$, in which SD_{diff} is the standard deviation of the difference scores observed between the two tests performed. Non-responders were defined as subjects who failed to achieve an increase that was greater than two times the TE away from zero. Since TE was 15.17 N, volunteers had to present at least 30.33 N of strength gain to be considered responders to the NHE training.

Table 1. *Periodization of the Nordic hamstring exercise training program.*

Week	Frequency	Sets	Repetitions
1	2	3	6
2	2	3	8
3	2	3	8 -10
4	2	3	10

RESULTS

Twenty-five soccer players completed the NHE training program and the assessments: 18.32±0.63 years old; 74.88±8.01kg; 1.80±0.08 m. All players had 100% attendance at the eight NHE training sessions. They significantly increased the eccentric knee flexor strength of both limbs (~13%), with large effect sizes (>0.9) from pre- to post-training assessments (Table 2). Nineteen out of the 25 players (76%) were classified as responders, while six players (24%) were classified as non-responders (Figure 2).

DISCUSSION

This study investigated the effect of adding an NHE training program into the preseason routine of a high-performance soccer club on eccentric knee flexor strength. The main findings were: (1) the NHE program significantly enhanced the players' eccentric knee flexor strength; and (2) around three-quarters of players were considered responders to the NHE training program.

The NHE was first described by Brockett et al.,[31] and there is strong evidence regarding its preventive effects on HSI. The systematic review with

Table 2. *Eccentric knee flexor strength (mean ± SD) before and after the Nordic hamstring exercise training program.*

	Pre-training	Post-training	Δ (N)	Δ (%)	p-value	Effect size
Left limb (N)	349.43±50.38	392.07±44.20	42.64±29.27	12.94±9.16	<0.001	0.92
Right limb (N)	356.73±49.08	400.35±42.55	43.62±33.03	13.05±10.04	<0.001	0.97

Δ (N) = absolute change (pre- to post-training, in Newtons); Δ (%) = percent change (pre- to post-training);

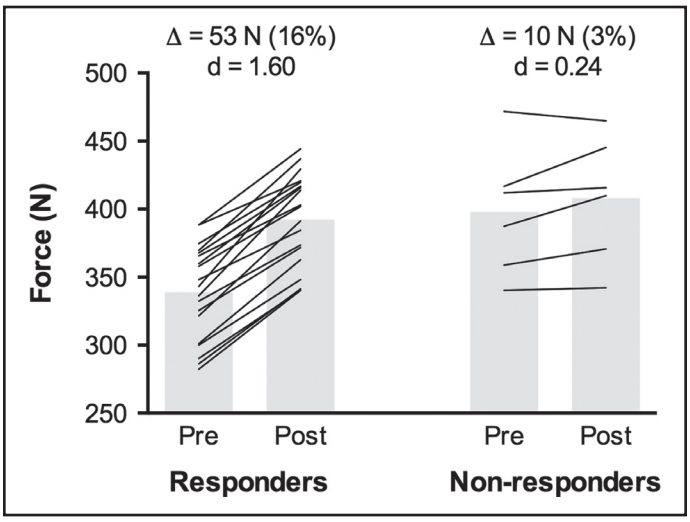

Figure 2. *Individual responsiveness to the NHE training program: responders (n = 19, 76%); non-responders (n = 6, 24%). Black lines indicate individual responses, and vertical grey bars show the group average values.*

meta-analysis by Al Attar et al.[18] included five prospective studies with soccer players of different competitive levels and concluded that the teams that used prevention programs which included the NHE reduced HSI rate by 51%. Corroborating those findings, the randomized controlled trial by Petersen et al.[17] included a large sample of 50 soccer teams (942 athletes) and verified that a 10-week training program with NHE reduced by 60% and 85% the new and recurring injuries, respectively.

Prospective studies have demonstrated the association between eccentric knee flexor strength and HSI rate in soccer players[8,10–12] and other athletic populations.[13,14] The link between eccentric strength and HSI is sometimes contradicted (for instance, studies by van Dyk et al.[32,33]), which is possibly related to the complex and multifactorial nature of sports injuries.[34] However, findings that soccer players with weak hamstrings at preseason have up to 4.4 times greater risk of in-season HSI than stronger players[8] support the importance of strength testing performed by most premier league football clubs[5,6] and highlight the relevance of strength gains provided by the NHE training program.

The percent increases of strength verified in the current study (~13%) are similar to those reported by Mjolsnes et al.[19] (i.e., ~11%) and Lovell et al.[21] (i.e., ~12%) in professional and amateur soccer players, respectively; while are slightly smaller than those found by Ishol et al.[20] (i.e., ~17%) in amateur soccer players. However, training programs with NHE in these previous studies took 10-12 weeks, suggesting effectiveness of the short-term NHE program employed in the current study. A previous study had already demonstrated that it is possible to obtain meaningful improvements of eccentric knee flexor strength with only four weeks of NHE training in university students.[23] Thus, the current study adds to literature that high-performance soccer players can also have meaningful eccentric knee flexor strength improvement in a short-term program with NHE.

Studies of professional soccer players have reported distinct levels of eccentric knee flexor strength during the NHE execution, ranging from ~261 N[8] to ~411 N.[35] The reason for the discrepancy observed among those athletes may be related to their competitive level,[36] but the under-20 players of the current study had similar baseline strength levels as their professional counterparts. Timmins et al.[8] evaluated 152 professional soccer players during the Australian preseason using a device similar to the prototype built for the current study. According to their logistic regression analysis, the risk of sustaining an HSI decreases ~9% for every 10 N eccentric strength increase of such muscle.[8] Therefore, it is plausible that the ~53 N of eccentric strength

increase observed in responders to the NHE training in the current study may have real repercussions on their susceptibility to HSI along the season.

To the best of the authors' knowledge, this is the first study to report the individual responsiveness to an NHE training program. This analysis is especially interesting for professionals working on the medical and coaching staffs; although the average values provide an idea of the team's behavior, it should be noted that a few athletes do not follow the same response trend observed in the group as a whole and should be screened. About three-quarters of the soccer players responded to the NHE training program proposed in the current study. All players were engaged in the same weekly training routine and all of them attended to the full NHE training program, thus adherence issues cannot explain the non-responders. One could speculate that players with high strength levels could be less responsive to NHE training after noting that non-responders had greater average strength values than responders at baseline (see figure 2). However, not all stronger players were non-responders and vice-versa, thus further investigation is needed to understand why some athletes positively respond to NHE training and others do not. However, findings of the current study support that most of players could benefit from a short-term hamstring strengthening program entirely feasible to the real context of a high-performance club's preseason.

It is important to highlight that, like all other sport injuries, the HSI has many causes.[9] The biceps femoris long head fascicle length,[8] the flexibility of the posterior thigh compartment,[37,38] the strength balance between hamstrings and quadriceps,[13,39] and the stabilization provided by the lumbo-pelvic muscles,[40] among other factors, are associated with athletes' susceptibility to HSI. The current study concentrated its intervention on the effects of training with NHE on only one risk factor (i.e., eccentric knee flexor strength), but this exercise has a potentially positive impact on other risk factors.[23,25]

Unfortunately, it was not possible to follow the behavior of the eccentric knee flexor strength of the athletes who had been in the intervention program during the rest of the season, nor to follow the injury rates of this group and compare them to the previous seasons to verify if the program with NHE had an actual effect on the incidence of HSI. In addition, a control group (without NHE training) was not included in this study because the club required that all players should be engaged in a preventive program using the NHE. Previous evidence supports that eccentric knee flexor strength remains unchanged in soccer players not engaged in an eccentric-overload exercise training routine.[19] However, the lack of a control group is a clear limitation of this study. This is the disadvantage of performing a clinical trial into the real-world of high-performance sports; conversely, the current study presents high ecological validity because it was done within the constraints and expectations of the soccer club.

CONCLUSION

The results of the current study demonstrated that it is possible to positively affect eccentric knee flexor strength including the NHE in a four-week preseason routine of a high-performance soccer club. In addition, the results showed that three-quarters of athletes engaged in this short-term periodization were responders to the NHE training. Therefore, given the difficulties to implement the longer NHE programs recommended by literature in the clubs' routine, more pragmatic training programs may be an effective alternative to address hamstring eccentric strengthening.

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